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CRT display image viewing quality improving method - positioning characters at sub-pixel locations by changing intensity values assigned to pixels

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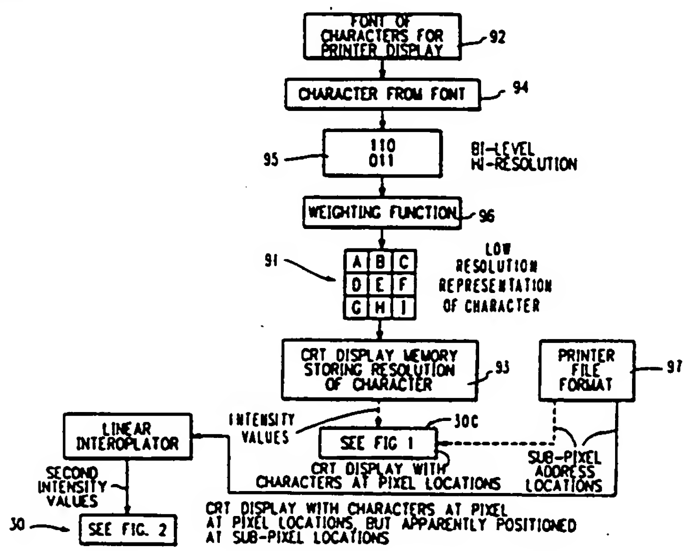
A CRT display memory is used to store respective low resolution representation for each character of a font which provides characters for an image in the printer display field. Intensity values are assigned to CRT pixels as if the low resolution representations of the number of characters were positioned by means of command signals which contained only pixel address locations.

The intensity values corresp. to certain pixels are then changed, by linear interpolationand the unchanged intensity value is assigned to a pixel whose intensity value is to be changed. Each pixel has still only one intensity value. The number of characters are apparently positioned at sub-pixel locations to improve the viewing quality of the CRT display image.

ADVANTAGE - Improvement of display image without increasing resolution or display memory storage space. (16pp Dwg.No.9/10) e
N87-056048



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(71) Applicant: International Business Machines Corporation
Old Orchard Road
Armonk, N.Y. 10504(US)

(72) Inventor: Gupta, Satish
28 Amber Drive
Croton-On-Hudson New York 10520(US)
Inventor: Lucas, Bruce David
5646 Hobart Street, Apt. 3
Pittsburgh Pennsylvania 15217(US)

(74) Representative: Appleton, John Edward
IBM United Kingdom Limited Intellectual
Property Department Hursley Park
Winchester Hampshire SO21 2JN(GB)

(54) **Virtual resolution displays.**

(57) A method for improving the viewing quality of a CRT display image without increasing resolution of the display. With the invention disclosed herein, characters are apparently positioned at sub-pixel locations to improve the viewing quality of a CRT display image. This apparent positioning is accomplished by changing intensity values assigned to pixels on a CRT display. In the preferred embodiment, the change in intensity values is effected by linear interpolation with intensity values of neighbouring pixels to yield second intensity values. These second intensity values, then, improve the viewing quality of the CRT display image.

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According to the invention there is provided a method for improving viewing quality of a CRT display image by apparently positioning a number of characters of the image at sub-pixel locations in the CRT display field in which the image appears, which characters are formed from a plurality of pixels and positioned at CRT pixel locations by means of command signals containing the sub-pixel address locations, each pixel having at most one intensity value assigned thereto, the locations being from printer file formats and identifying printer pixel locations in a printer display field, which has a higher resolution than the CRT display, said method comprising the steps of:

(a) storing in a CRT display memory at most one respective low resolution representation for each character of a font which provides characters for an image in the printer display field;

(b) assigning intensity values to CRT pixels as if the low resolution representations of the number of characters were positioned by means of command signals which contained only pixel address locations; and

(c) changing intensity values, obtained in step (b) of certain of the pixels forming the number of characters to corresponding second intensity values, by linear interpolation, the intensity value, assigned to a pixel whose intensity value is to be changed, being changed by linear interpolation, with the unchanged intensity value assigned to a pixel whose intensity value is to be changed, each pixel still having only one intensity value assigned thereto, whereby the number of the characters are apparently positioned at sub-pixel locations to improve the viewing quality of the CRT display image.

In order that the invention may be fully understood a preferred embodiment thereof will now be described with reference to the accompanying drawings, in which:-

Fig. 1 is a representation of CRT display image of characters in a CRT display using format commands from a printer without apparent sub-pixel positioning;

Fig. 2 represents an improvement of the viewing quality of the CRT display image quality of FIG. 1 by the apparent positioning of characters at sub-pixel locations in accordance with the present invention;

Fig. 3A represents a CRT display field with intensity values assigned to CRT pixels;

Fig. 3B represents a CRT display field with second intensity values assigned to CRT pixels;

Fig. 4A represents an enlarged CRT display image of characters of an image not using the method of this invention;

Fig. 4B represents an enlarged CRT display image of characters, positionable at pixel locations, but which have been apparently positioned at sub-pixel locations;

FIGS. 5A, B, and C illustrate the method - (linear interpolation) of changing the intensity values assigned to the CRT pixels to second intensity values;

Fig. 6 represents the logic flow diagram of the algorithm to accomplish the linear interpolation of FIG. 5;

Fig. 7A schematically illustrates the assignment of bi-level intensity values to printer pixels in the bi-level printer display which is of higher resolution than that of the CRT display (7B);

Fig. 7B schematically illustrates the assignment of respective intensity values to CRT pixels - (also referred to as "pixels"), in the CRT display which is of lower resolution than that of the printer display (7A);

Fig. 8A represents a CRT pixel with printer pixels underlying and surrounding an area that contains at least a given CRT pixel;

Fig. 8B represents the CRT pixel (also called "pixel") of FIG. 8A with its assigned intensity value;

Fig. 8C illustrates the weighting function used to obtain weighted averages of the bi-level intensity values of the printer pixels of FIG. 8A which weighted averages are added to obtain the intensity value of FIG. 8B;

Fig. 9 schematically illustrates obtaining low resolution representations for each of the characters in a font which provides the characters for the images on the printer display, storing these low resolution representation in memory and changing intensity values to second intensity values; and

Fig. 10 schematically illustrates the apparatus and method for changing of intensity values by linear interpolation with intensity values of adjacent pixels.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, and more particularly to FIG. 1, there is shown an image of characters in a CRT display, with unchanged intensity values. Notice, in FIG. 1, the close spacing 12 between the "t" and the "i" in the word "resolution". FIG. 2 shows improved viewing quality of the CRT display image, using the methods of this invention. Here, the spacing (12') is increased to improve the viewing quality image. Thus, in going from FIG. 1, to FIG. 2, one sees an apparent shift of the character "i" by a sub-pixel distance to the right. Or, in FIG. 2, one sees an apparent positioning of the character "i" at a sub-pixel loca-

Adjacent pixels of a given pixel could also be pixels above and below the given pixel.

It should be observed that the linear interpolation was performed in only the horizontal direction or along the pixels in a given row, which is the direction in which letters or characters are placed to form a word. In most cases it was found that interpolation in the vertical direction (up and down the display) was not necessary. Slight sub-pixel vertical variations in the placement of characters on the CRT display did not do much to improve image display quality. More simply, interpolation should be in the direction in which letters or characters are placed to form a word. For example, the letters of the word "the" are placed in a horizontal direction - (across the page), not in a vertical direction (up and down the page). Furthermore, it was also found that one interpolation per pixel was sufficient to improve image quality on the CRT display.

The terms "horizontal direction" and "horizontally" shall refer to the direction in which characters are placed to form a word. Thus, "vertical" or "above and below" shall refer to a direction which is orthogonal to the "horizontal direction."

The logic flow diagram, of the algorithm used to accomplish the interpolation in this preferred embodiment, is described in the above paragraph and is shown in FIG. 6. Referring to FIG. 6, Blocks 60 and 62 show that 0 and a_1 are the first pair of intensity values to be interpolated with each other. Block 64 contains instructions to perform the actual interpolation to obtain second intensity values, "Sample (x)". Δx in block 64 represents the sub-pixel distance by which a character is to be shifted. For example, in FIG. 5B, Δx is 0.5. Applying the above parameters (0, a_1 and Δx = 0.5), the output of block 64 is $[(0)(0.5) + (a_1)(1-0.5)] = [0.5a_1]$ which value would be the second intensity for the pixel on the extreme left of a particular row, which pixel is represented by x_1. Block 66 represents instructions to repeat the above for a_1 and a_2. Thus, the output of block 64 would then be $[a_1(0.5) + a_2(1-0.5)] = [0.5a_1 + 0.5a_2]$. This latter value would be the second intensity value for the pixel x_1+1, adjacent to, and to the right of, the pixel x_1. Decision block 68 and block 69 contain instructions to repeat the above process up to and including i = n. Thus, the last two intensity values to be interpolated would be a_{n-1} and a_n, and the last second intensity value (the value assigned to the right most pixel of the row) would be $[a_{n-1}(0.5) + a_n(1-0.5)] = [0.5 a_{n-1} + 0.5a_n]$.

The square brackets are used above to indicate that the greatest integer in the value inside the brackets is to be used. For example, [1.9] = 1 and [2/5] = 2.

Referring to FIG. 7A, there is shown a - schematic of a bi-level printer display field 70 with printer pixels 71 and some bi-level intensity values (72) assigned to the printer pixels or pixels of the printer display field. The term bi-level implies that each printer pixel can only be assigned an intensity value of "0" or "1". FIG. 7B, on the other hand, shows a CRT display field 30B with CRT pixels 31B and some assigned intensity values (32B) which are multi-level values. The term multi-level implies that each CRT pixel 31B can have a range of values, say, for example, from 0 to 31. FIG. 7B represents pixels on the CRT display field 30B covering the same corresponding area on the printer display field 70. That is to say, the printer pixels 71 of FIG. 7A underlie the CRT pixels 31B of FIG. 7B. Notice, that, in the same corresponding area, there are many more printer pixels 71 than CRT pixels 31B, i.e. the printer display field 70 is of higher resolution than that of the CRT display field 30B of a CRT display.

Referring to FIGS. 8A, 8B, and 8C, there is shown the means of assigning an intensity value to a pixel 31C of a CRT display. The larger square 31C, enclosed within the thick lines 88, of FIG. 8A represents a larger pixel of the low resolution CRT display field 30 or 30B, and the smaller squares 71C, within and surrounding the larger square, represent printer pixels 71C of the high resolution printer display field. FIG. 8B represents the larger pixel 31C shown in FIG. 8A to which an intensity value (32C) is to be assigned. The gridded area 85 of FIG. 8A represents an area on the printer display that contains at least the given CRT pixel 32C (see FIG. 8B) on the CRT display. All the smaller squares 71C of FIG. 8A represent the printer pixels 71C underlying area 85. The shaded areas of FIG. 8A represent the printer pixels whose bi-level intensity value is "1" and the unshaded areas represent the printer pixels whose bi-level intensity value is "0". FIG. 8C represents the preferred weighting function to be used, although other weighting functions could be used with equally satisfactory results. The numbers (89) in the printer pixels 71C of FIG. 8A represent weighted values assigned to the particular printer pixels, according to the weighting function of FIG. 8C. Each weighted value is multiplied by its corresponding bi-level intensity value to produce a given product. The given products are then added to yield a first intensity value (25 in this case) for the low resolution pixel of FIG. 8B. The method of obtaining multi-level intensity values, described above is known as anti-aliasing and is described in a Ph.D. thesis by F. C. Crow, entitled "The Aliasing Problems in Computer -Synthesized Shaded Images", University of Utah, March, 1976. The relative merits of using various weighting functions is described in article by John E. Warnock,

103 and 104 are then applied to adder 105 which yields an output of $a_i\Delta x\ a_{i-1}\ 1(a-\Delta x)$. This latter output represents the second intensity value to be assigned to the pixel whose intensity value was a_{i-1} on the CRT display. a_1 represents the pixel in the extreme left of a given row. To change a_1 to a second intensity value, 0 and a_1 are loaded into registers 101 and 102, respectively. The second intensity value replacing a_1, is then found in the same manner as described above for the value replacing a_{i-1}. The above process is repeated for each row forming the character which is to be apparently positioned at a sub-pixel location. The above procedure is then repeated for all characters to be apparently positioned. These second intensity values are then loaded into a CRT display whereby the characters are apparently positioned at a sub-pixel location to improve display viewing quality (see FIG. 2).

It is thought that method for improving display image quality on a CRT display and many of its attendant advantages will be understood from the foregoing description. It will be apparent that various changes may be made in the form, construction and arrangement of this invention without departing from the spirit and scope of this invention or sacrificing all of its material advantages. The description above is merely a preferred or exemplary embodiment of the invention herein.

Claims

1. A method for improving viewing quality of a CRT display image by apparently positioning a number of characters of the image at sub-pixel locations in the CRT display field in which the image appears, which characters are formed from a plurality of pixels and positioned at CRT pixel locations by means of command signals containing the sub-pixel address locations, each pixel having at most one intensity value assigned thereto, the locations being from printer file formats and identifying printer pixel locations in a printer display field, which has a higher resolution than the CRT display, said method comprising the steps of:

(a) storing in a CRT display memory at most one respective low resolution representation for each character of a font which provides characters for an image in the printer display field;

(b) assigning intensity values to CRT pixels as if the low resolution representations of the number of characters were positioned by means of command signals which contained only pixel address locations; and

(c) changing intensity values, obtained in step (b) of certain of the pixels forming the number of characters to corresponding second intensity values, by linear interpolation, the intensity value, assigned to a pixel whose intensity value is to be changed, being changed by linear interpolation, with the unchanged intensity value assigned to a pixel whose intensity value is to be changed, each pixel still having only one intensity value assigned thereto, whereby the number of the characters are apparently positioned at sub-pixel locations to improve the viewing quality of the CRT display image.

2. A method as recited in Claim 1, wherein the linear interpolation comprises at most one linear interpolation for each CRT pixel forming the number of characters, the interpolation being only with the intensity values assigned to two adjacent pixels in the same row or between one intensity value assigned to a pixel in the row and an intensity value assigned to a pixel horizontally adjacent to the row.

3. A method for improving the viewing quality of a CRT display image by apparently positioning a number of characters appearing therein, which characters are formed from a plurality of pixels and are positionable at pixel locations by means of command signals containing sub-pixels address locations in the CRT display field in which the image is formed, the address locations being from printer file formats and corresponding to printer pixel locations in a printer display field, which has a higher resolution than the CRT display in which the image appears, said method comprising the steps of:

(a) assigning respective intensity values to pixels, so that each pixel has, at any given time, only one intensity value, and so that, the intensity value of any given pixel, is proportional to the sum of weighted averages of bi-level intensity values of printer pixels underlying an area that contains at least the given pixel; and

(b) changing certain of the intensity values obtained in step (a), of the pixels forming the number of the characters, to corresponding second intensity values by linear interpolation, the intensity value, assigned to a pixel whose intensity value is to be changed, being changed by lineary interpolation, with the unchanged intensity value assigned to a pixel adjacent to the pixel whose intensity value is to be changed, each pixel still having one one intensity value assigned thereto, whereby the number of the characters are apparently positioned at sub-pixel locations to improve the viewing quality of the CRT display image.

FIG. 1

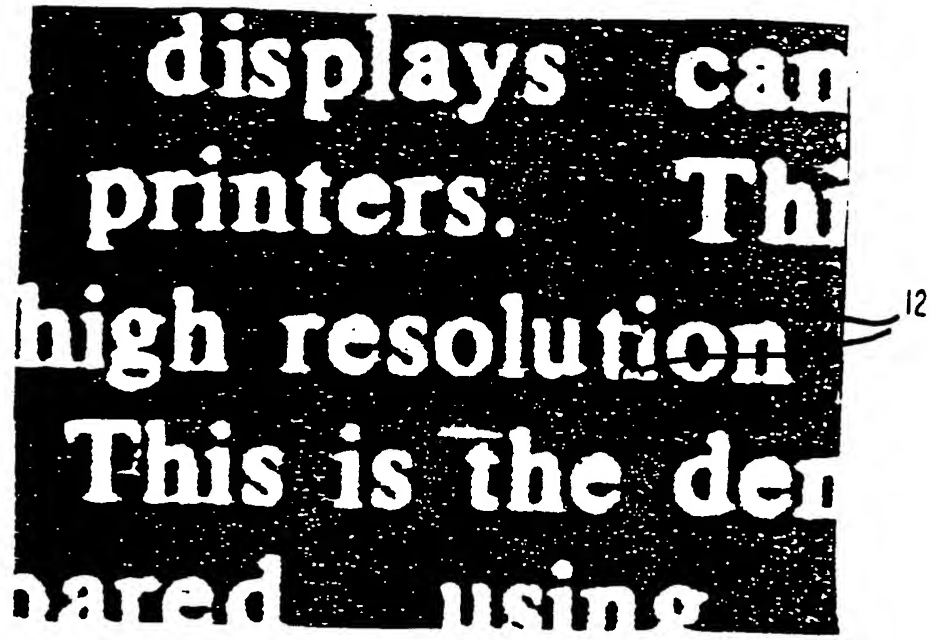
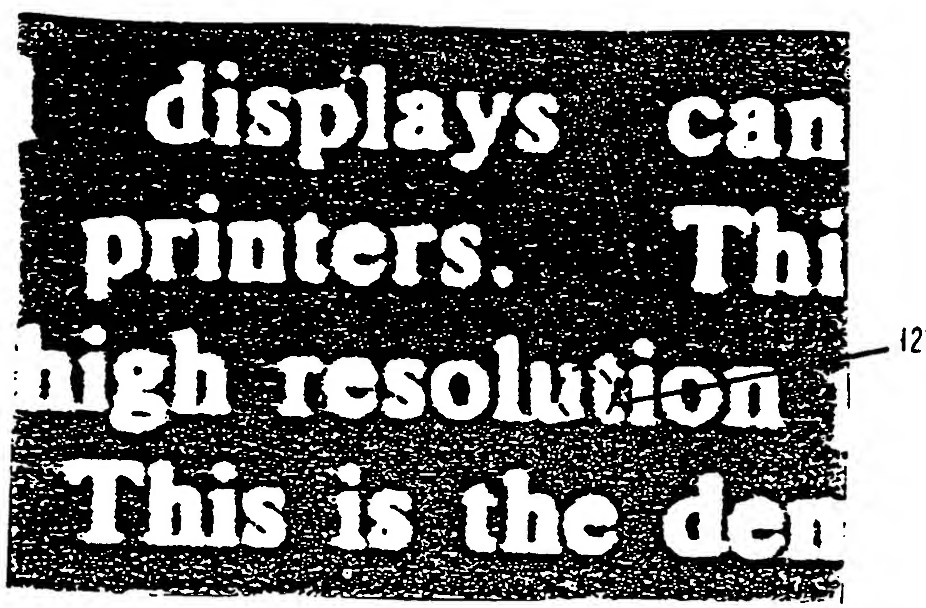

displays can
printers. Thi
high resolution
This is the den
pared using
12

FIG. 2


displays can
printers. Thi
high resolution
This is the den
12'

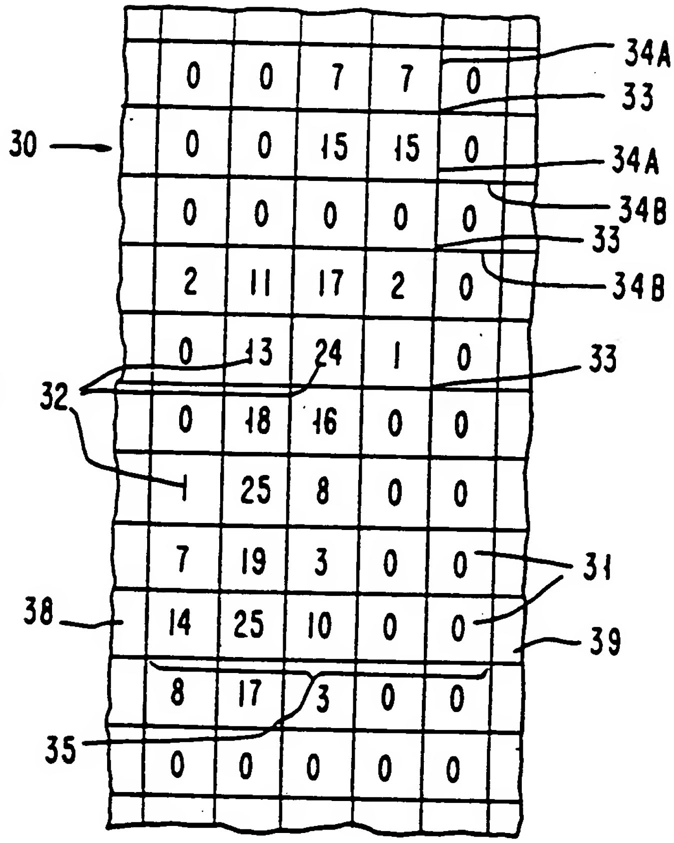

34A
33
30
34A
34B
33
34B
33
32
31
38
39
35
0 0 7 7 0
0 0 15 15 0
0 0 0 0 0
2 11 17 2 0
0 13 24 1 0
0 18 16 0 0
1 25 8 0 0
7 19 3 0 0
14 25 10 0 0
8 17 3 0 0
0 0 0 0 0

FIG. 3A

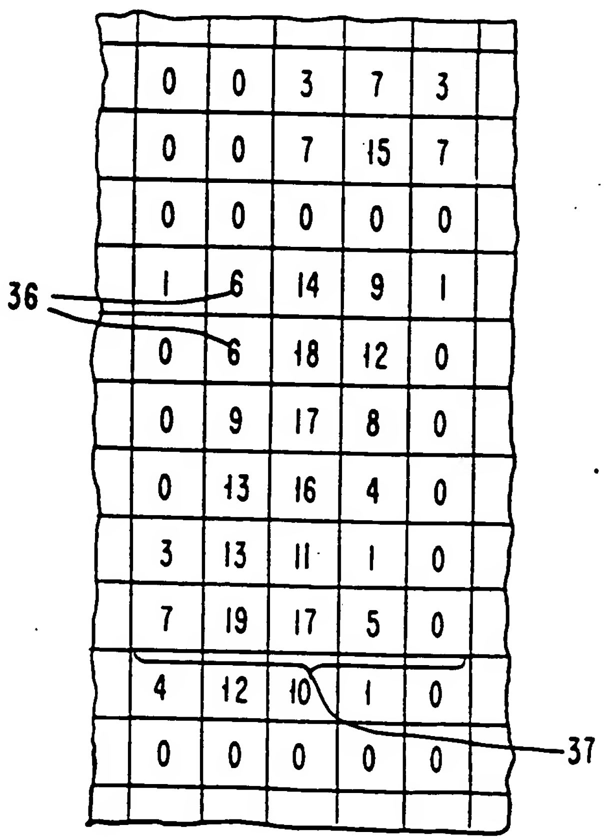

36
37
0 0 3 7 3
0 0 7 15 7
0 0 0 0 0
1 6 14 9 1
0 6 18 12 0
0 9 17 8 0
0 13 16 4 0
3 13 11 1 0
7 19 17 5 0
4 12 10 1 0
0 0 0 0 0

FIG. 3B

FIG. 4A

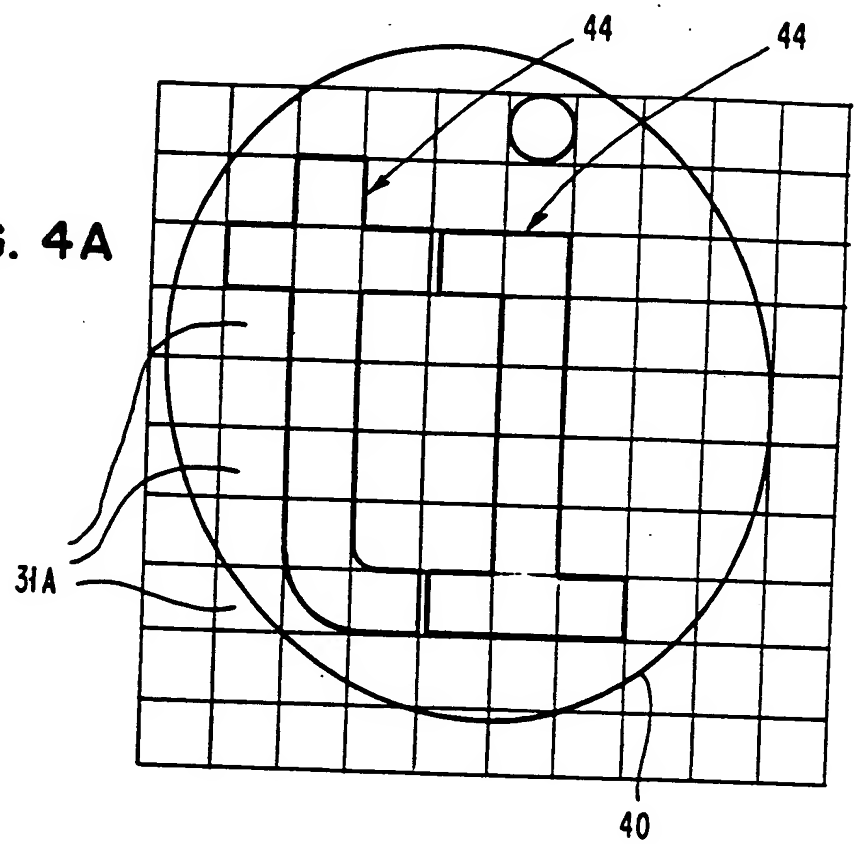


FIG. 4B

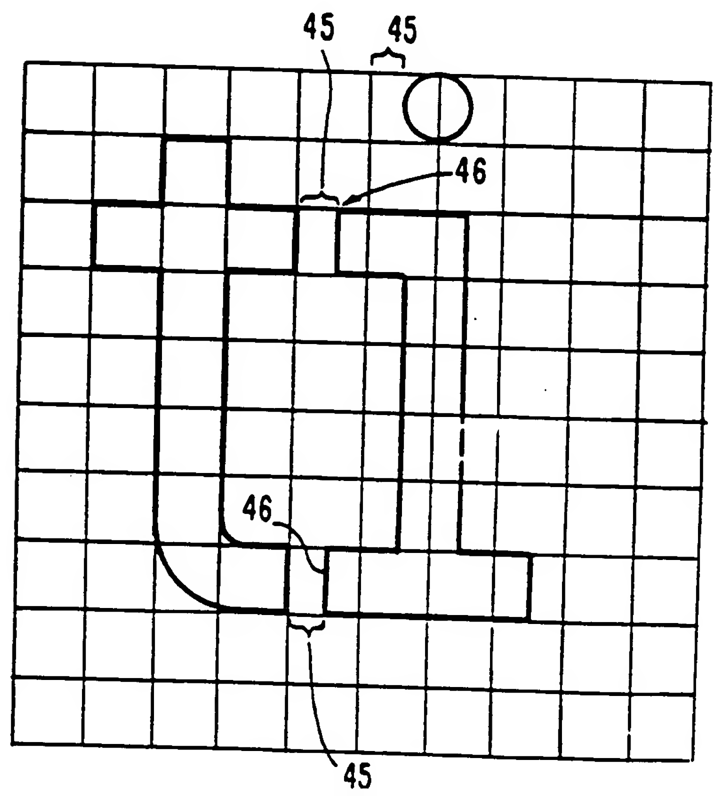


FIG. 5A

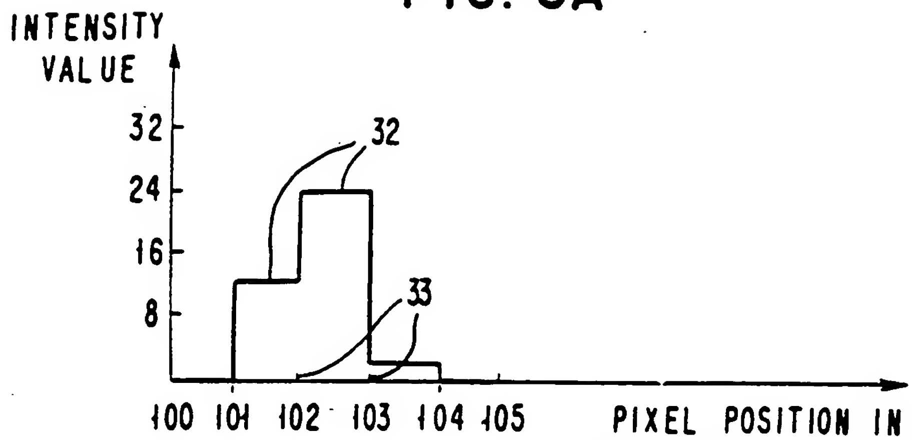


FIG. 5B

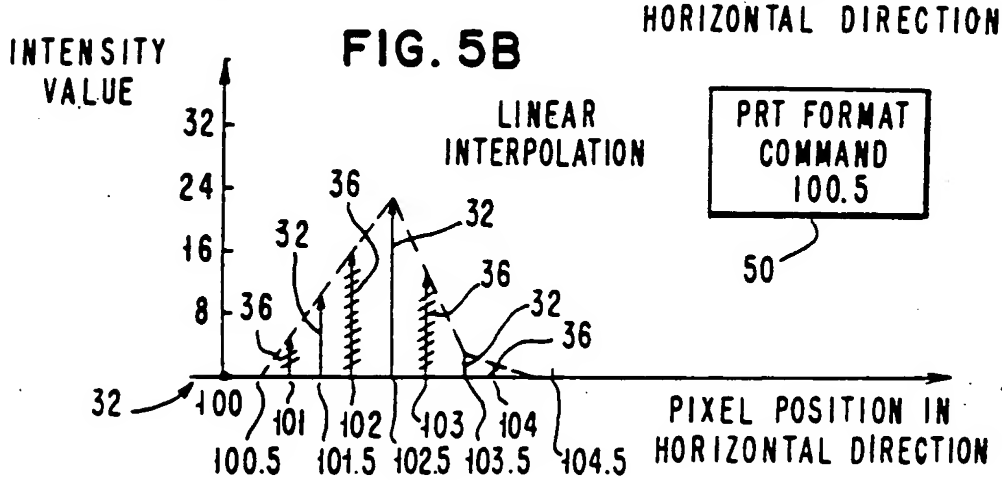


FIG. 5C

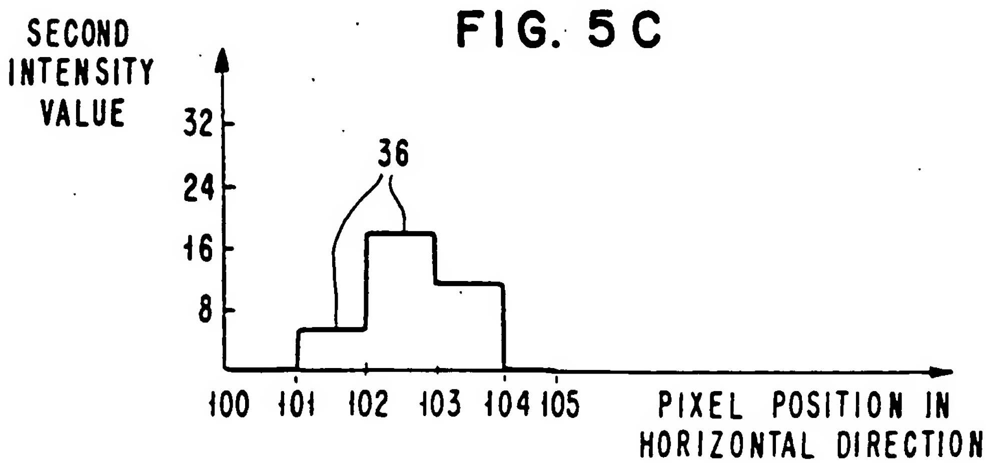


FIG. 6
LOGIC
FLOW DIAGRAM
OF METHOD

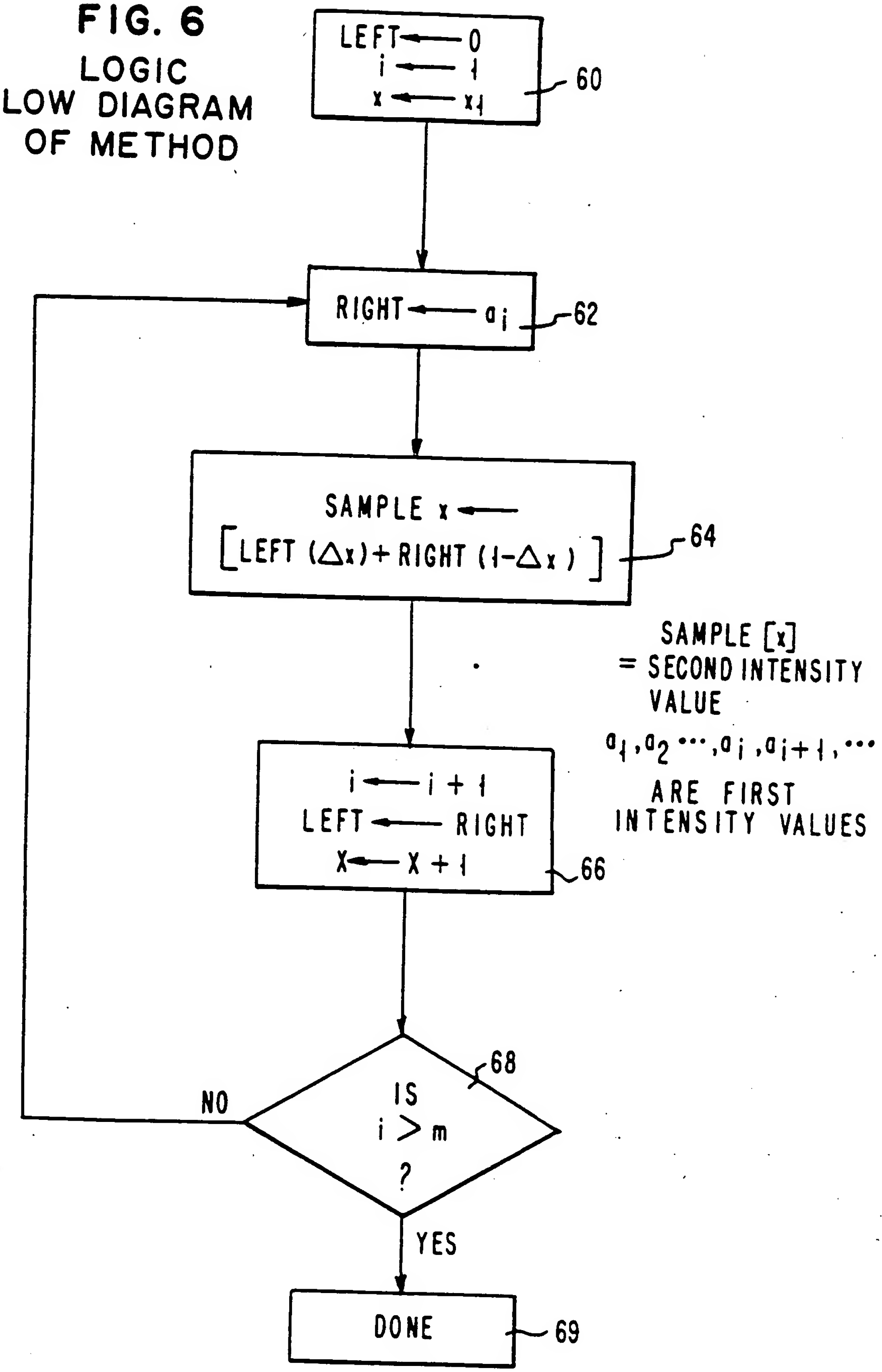


FIG. 7A

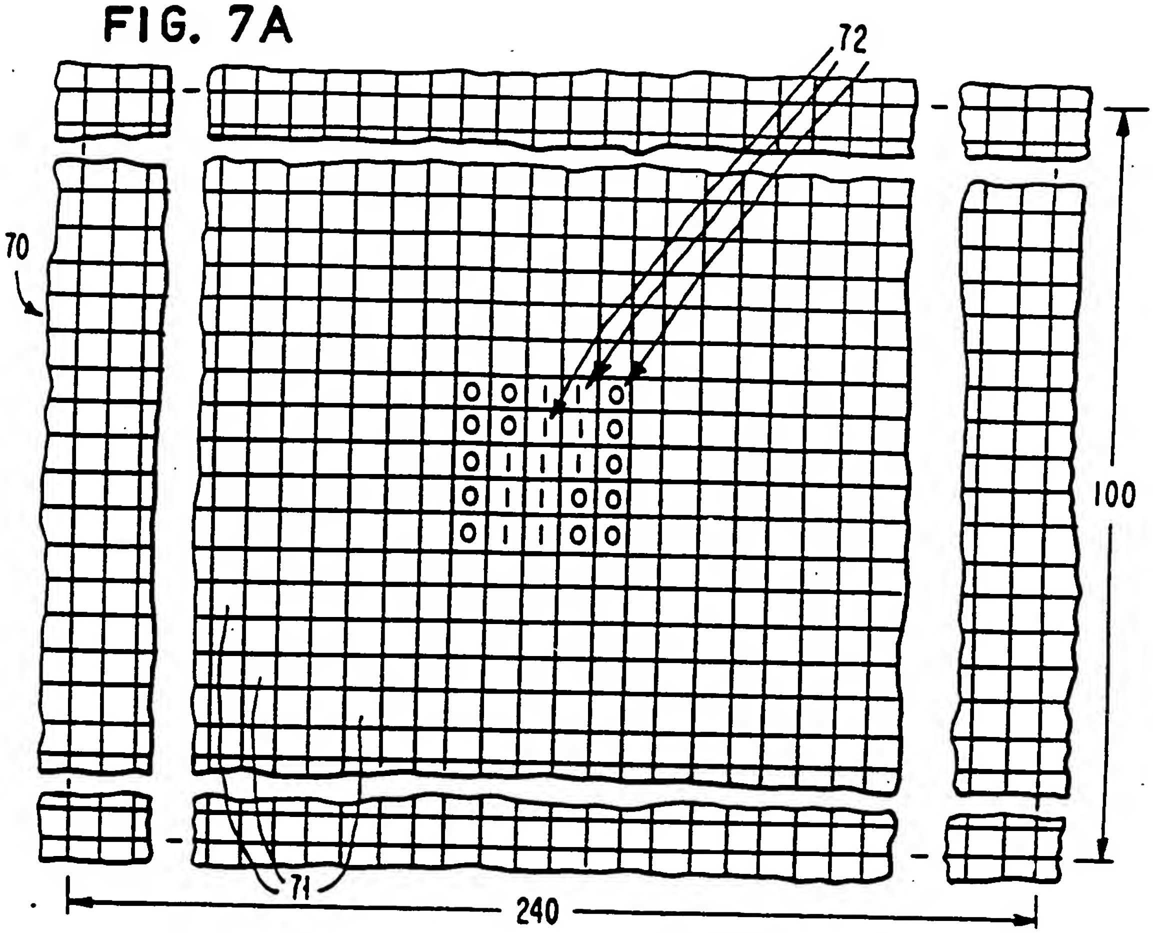

72
70
0 0 1 1 0
0 0 1 1 0
0 1 1 1 0
0 1 1 0 0
0 1 1 0 0
100
71
240

FIG. 7B

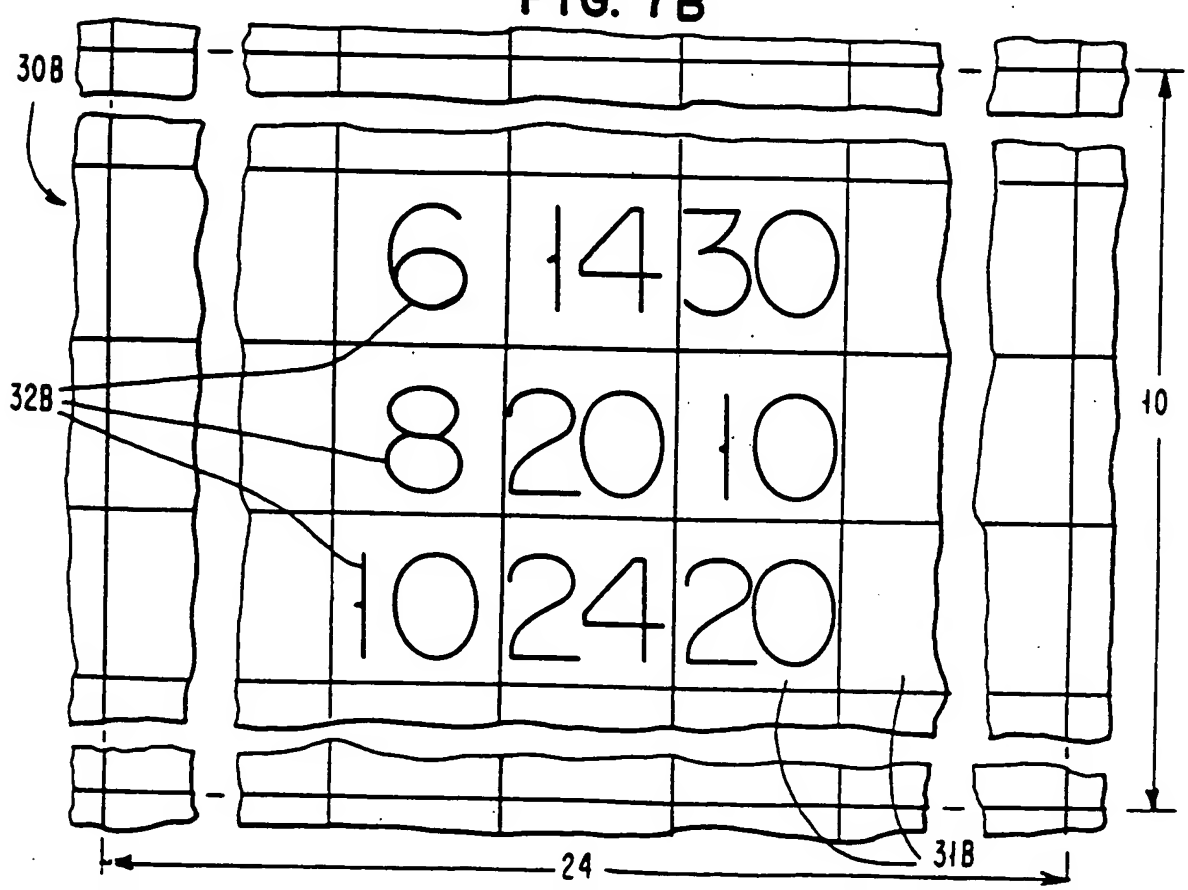

30B
6 14 30
8 20 10
10 24 20
32B
10
31B
24

FIG. 8A

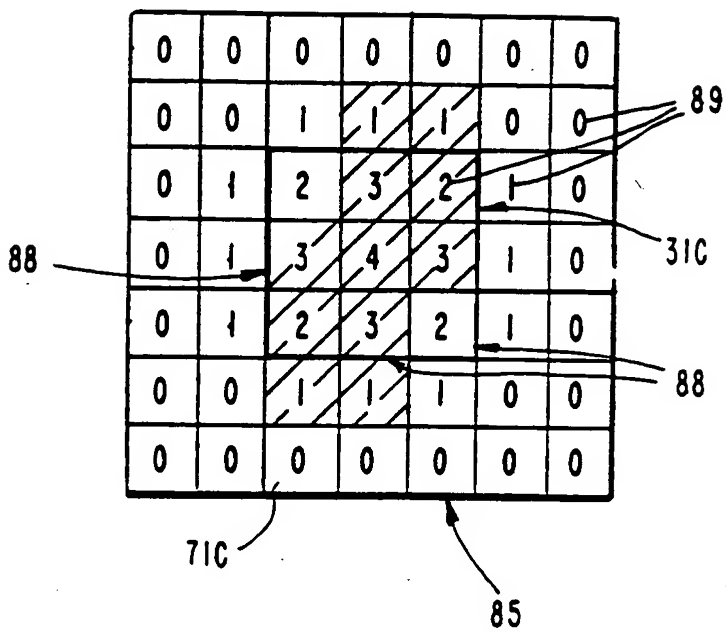


FIG. 8B

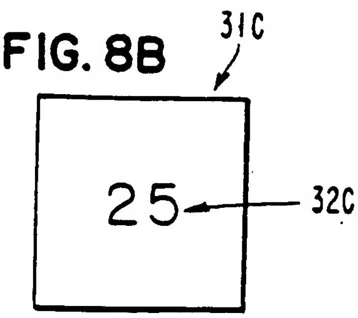
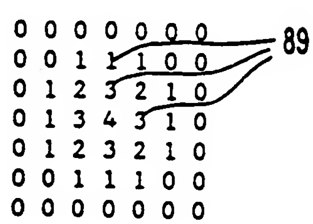


FIG. 8C



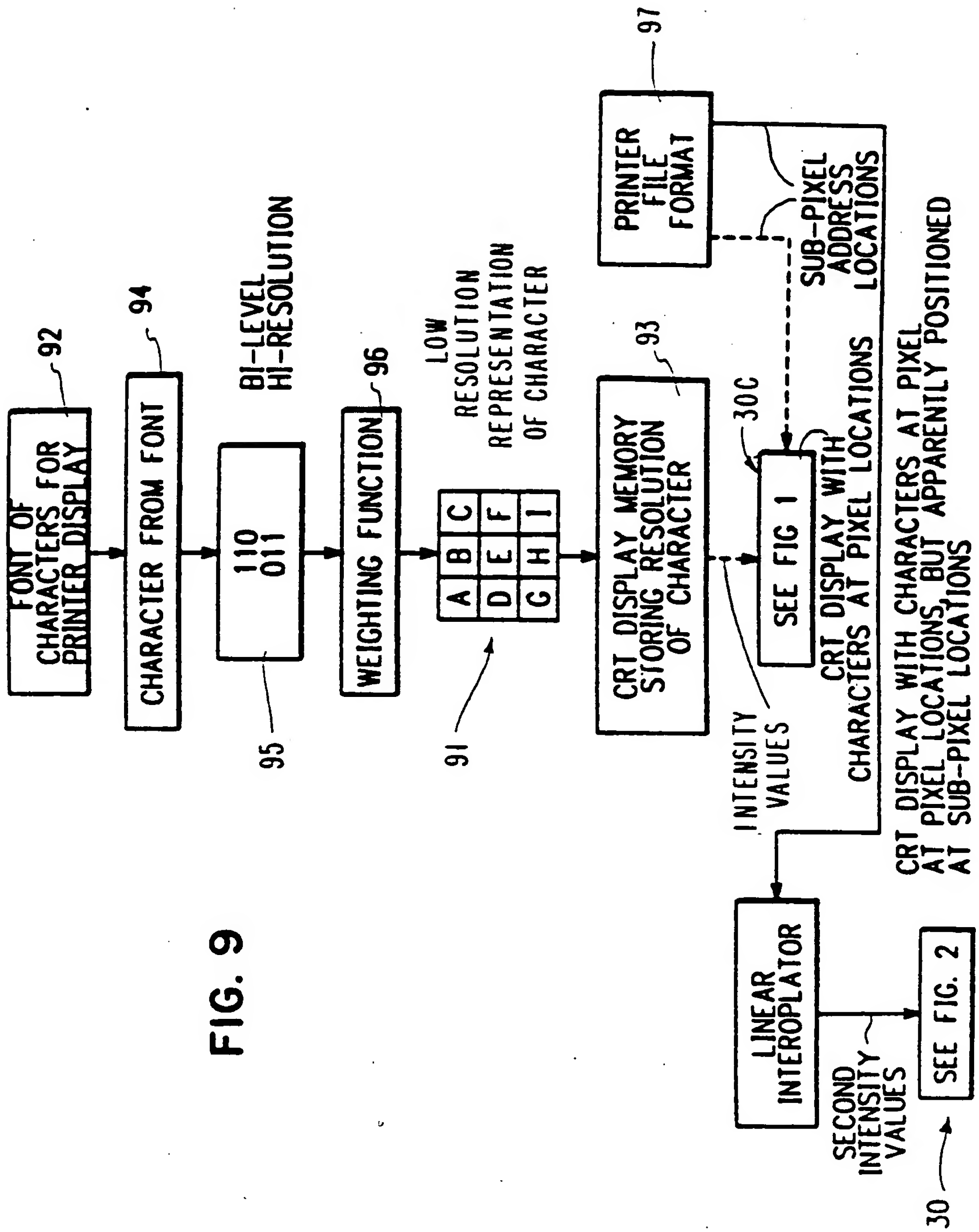
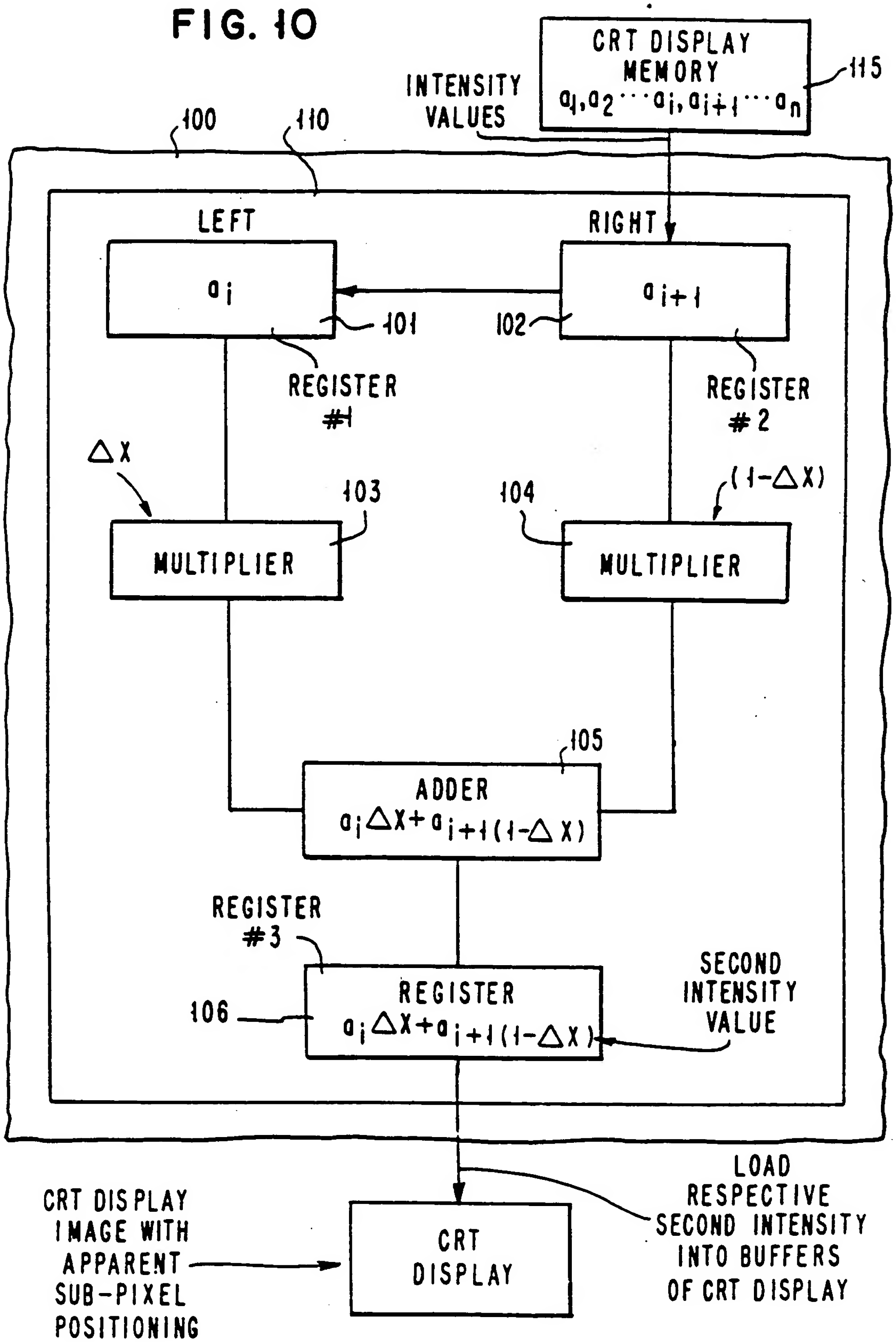

FONT OF CHARACTERS FOR PRINTER DISPLAY
92
CHARACTER FROM FONT
94
110
011
95
BI-LEVEL HI-RESOLUTION
WEIGHTING FUNCTION
96
A B C
D E F
G H I
91
LOW RESOLUTION REPRESENTATION OF CHARACTER
CRT DISPLAY MEMORY STORING RESOLUTION OF CHARACTER
93
INTENSITY VALUES
SEE FIG 1
30C
CRT DISPLAY WITH CHARACTERS AT PIXEL LOCATIONS
PRINTER FILE FORMAT
97
SUB-PIXEL ADDRESS LOCATIONS
CRT DISPLAY WITH CHARACTERS AT PIXEL LOCATIONS, BUT APPARENTLY POSITIONED AT SUB-PIXEL LOCATIONS
LINEAR INTEROPLATOR
SECOND INTENSITY VALUES
SEE FIG. 2
30

FIG. 9

FIG. 10


CRT DISPLAY MEMORY
$a_1, a_2 \cdots a_i, a_{i+1} \cdots a_n$
115
INTENSITY VALUES
100
110
LEFT
RIGHT
a_i
a_{i+1}
101
102
REGISTER #1
REGISTER #2
ΔX
(1-ΔX)
103
104
MULTIPLIER
MULTIPLIER
105
ADDER
$a_i \Delta X + a_{i+1}(1-\Delta X)$
REGISTER #3
106
REGISTER
$a_i \Delta X + a_{i+1}(1-\Delta X)$
SECOND INTENSITY VALUE
LOAD RESPECTIVE SECOND INTENSITY INTO BUFFERS OF CRT DISPLAY
CRT DISPLAY IMAGE WITH APPARENT SUB-PIXEL POSITIONING
CRT DISPLAY